Instruction Manual

for

A.C. Precision Millivoltmeter

Type VF252

THE SOLARTRON ELECTRONIC GROUP LTD
Thames Ditton, Surrey, England

SOLARTRON

Instruction Manual

for

A.C. Precision Millivoltmeter

Type VF252

Issue No. : Four

Mod. Ref. : 252/108

Date : Oct. 1960

THE SOLARTRON ELECTRONIC GROUP LTD

THAMES DITTON · SURREY ENGLAND

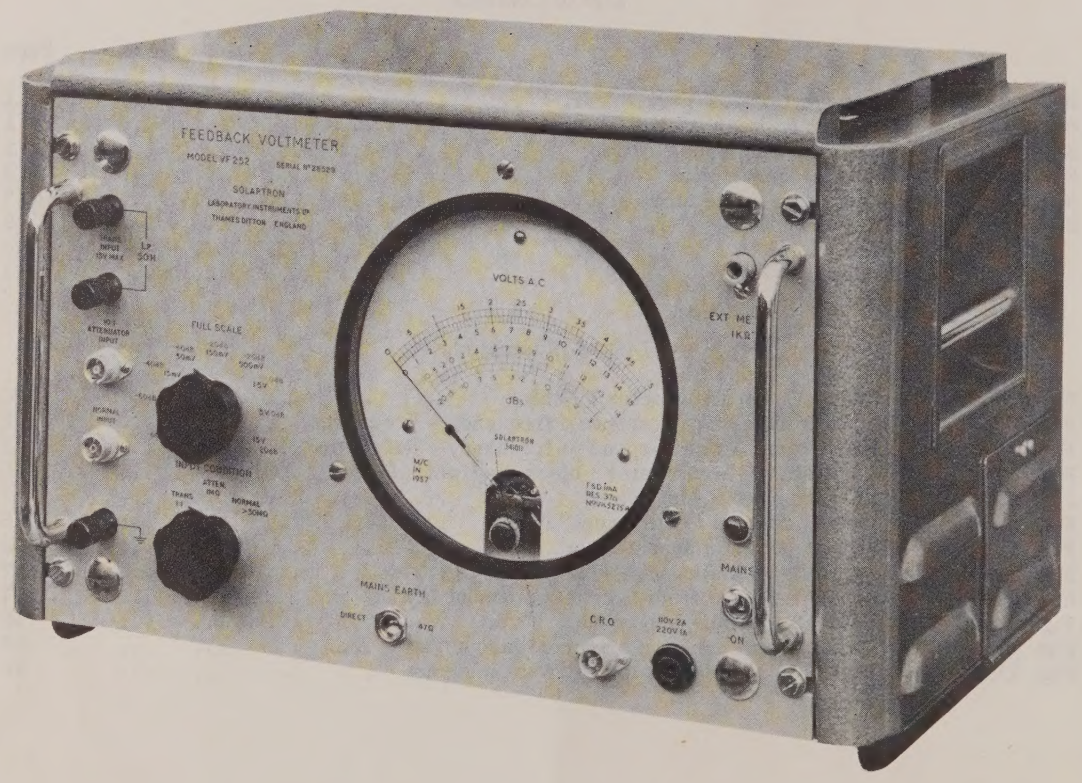
Telephone : EMBerbrook 5522 *Telegrams and Cables : Solartron, Thames Ditton*

List of Contents

		Page
Section 1.	Introduction	1
Section 2.	Operating Instructions	1
Section 3.	Performance Specification	1
Section 4.	Circuit Description	3
Section 5.	Setting up Procedure	7
Section 6.	Quiescent Levels	9
	Table of Faults	10
	Components List	12

List of Illustrations

Frontispiece.	The A.C. Millivoltmeter VF252	IV
Fig. 1.	Input transformer response : frequency - % error	2
Fig. 2.	Input transformer response : frequency - dB error	3
Fig. 3.	The A.C. Millivoltmeter : block diagram	6
Fig. 4.	Arrangement of test gear	7
Fig. 5.	Bottom chassis : component layout	16
Fig. 6.	Right side : Component layout	16
Fig. 7.	Left side : Component layout	17
Fig. 8.	Switch 1 viewed from rear : Component layout	17
Fig. 9.	Switch 2 : Component layout	18
Fig. 10.	Rear of front panel : Component layout	18
Fig. 11.	The A.C. Millivoltmeter : Circuit diagram	19



Frontispiece The A. C. Millivoltmeter VF252

SECTION 1

INTRODUCTION

The Precision A. C. Milli-voltmeter VF. 252 is a high-grade laboratory measuring instrument with an accuracy of 1% on all ranges and an operating bandwidth of 100 kc/s. The circuit utilises feedback amplification throughout for good gain stability, and in the meter stage the feedback technique eliminates for all practical purposes the effects due to variations in rectifier characteristics. The mechanical design lays stress on the layout of components for cooling purposes, ease of operation and good accessibility when servicing.

SECTION 2

OPERATING INSTRUCTIONS

General

2.1 Before using the instrument ensure that the mains voltage selector panel is correctly set.

Connections to the A. C. Milli-voltmeter

2.2 It is recommended that one earth connection only be made from the work on test to the A. C. Milli-voltmeter, in order to eliminate the possibility of error voltage arising from loop currents. Further, when either the work or any auxiliary equipment connected to the work has a direct earth connection, the A. C. Milli-voltmeter should be set to the 47 ohms earth by means of the switch in the front panel. This connects a 47 ohms resistor between the negative earth of the instrument and the mains earth, thus eliminating once again the possibility of a loop current.

2.3 When the equipment connected to the A. C. Milli-voltmeter is fully isolated, the above-mentioned switch should, of course, be set for direct earth. The desired input conditions can be obtained by using the appropriate input connections, i. e. two terminals for transformer input, a co-axial socket for attenuator input, and a co-axial socket for normal input, in conjunction with the input condition switch.

Operating the A. C. Milli-voltmeter

2.4 The A. C. Milli-voltmeter is extremely simple to use, and to take a voltage reading the procedure is as follows:-

(i) Set the input condition switch to the required input condition;

(ii) Set the range switch to a suitable range;

(iii) Make connection to the voltage it is required to measure;

(iv) The voltage is then indicated on the A. C. Milli-voltmeter.

SECTION 3

PERFORMANCE SPECIFICATION

General

3.1 The A. C. Milli-voltmeter has three input conditions, namely:-

Normal
Attenuator
Transformer

Signal Sensitivity Ranges

3.2 The Sensitivity ranges are 1. 5mV, 5mV, 15mV, 50mV, 150mV, 500mV, 1. 5V, 5V and 15V for full-scale deflection.

Nominal Frequency Range

3.3 The nominal frequency range is 10 c. p. s. to 100 K. c. p. s.

Accuracy of Indication

3.4 (i) Normal input

The indicated values on all ranges are accurate to within ±1% of full-scale deflection at 1 K. c. p. s. Over the frequency range 15 c. p. s. to 100 K. c. p. s. the indicated values on all ranges are within ±1% of full-scale deflection of the indicated values at 1 K. c. p. s. At 10 c. p. s., the indicated values on all ranges are within +0% -1. 5% of full-scale deflection of the indicated value at 1 K. c. p. s.

(ii) Input attenuator

The 1M-ohm input attenuator has a ratio of 10 : 1. This attenuator is adjusted to an accuracy of ±. 5% at 1 K. c. p. s. and is capacity compensated.

(iii) Input transformer

The useful frequency range of the input transformer is from 10 c.p.s. to 100 K.c.p.s. For details of frequency response, see frequency response curves (Figs. 1 & 2).

Input Impedance

3.5 (i) Normal input

Normal input impedance is greater than 50M-ohms, shunted by a capacitor of approximately 20pFd.

(ii) Attenuator input

The attenuator impedance is 1M-ohms.

(iii) Transformer input

The primary inductance is 50 Hy.

C.R.O. Output Volts

3.6 When the A.C. Milli-voltmeter indicates full-scale deflection, the voltage at the C.R.O. output socket is approximately 2.5V.

C.R.O. Output Signal/Noise Ratio

3.7 The noise voltage is measured at C.R.O. output socket when normal input socket is closed on a 1M-ohm resistor.

At the 15V - 15mV ranges the noise level is greater than 40db down on full-scale deflection.

On the 5mV range the noise level is greater than 35db down on full-scale deflection.

On the 1.5mV range the noise level is greater than 30db down on full-scale deflection.

Mains Requirements

3.8 This instrument is suitable for operation on 110V/220V ±20V 50-60 c.p.s. and the consumption is 80 VA.

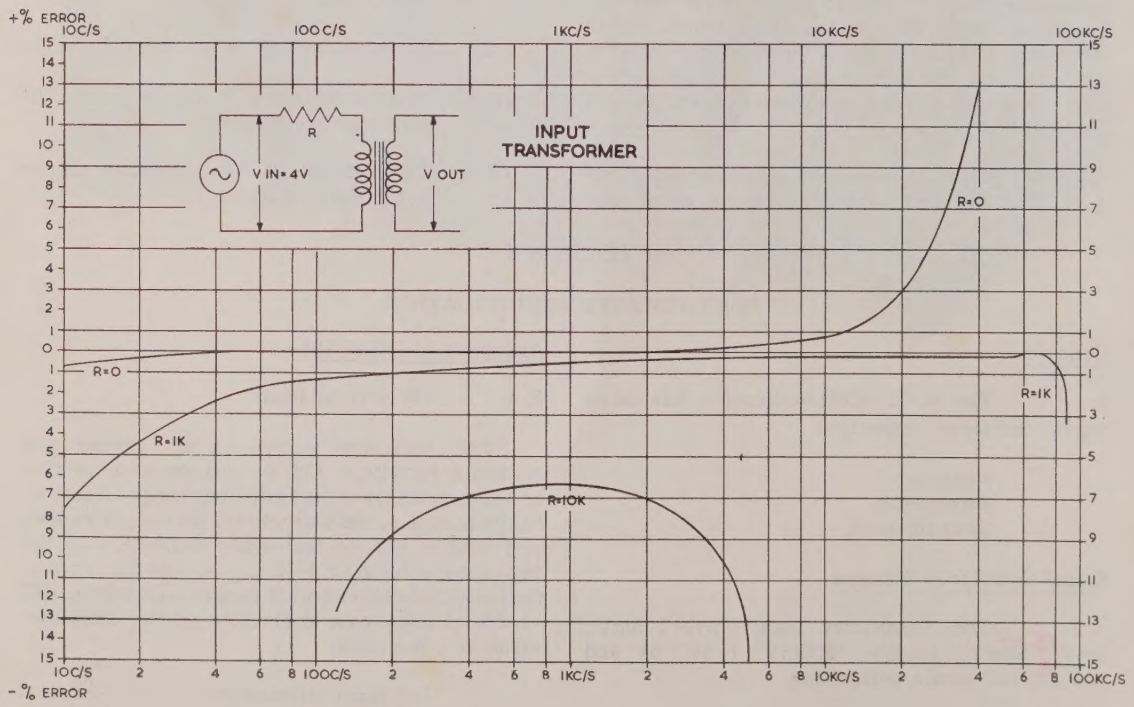


Fig. 1. Input transformer response : frequency - % error

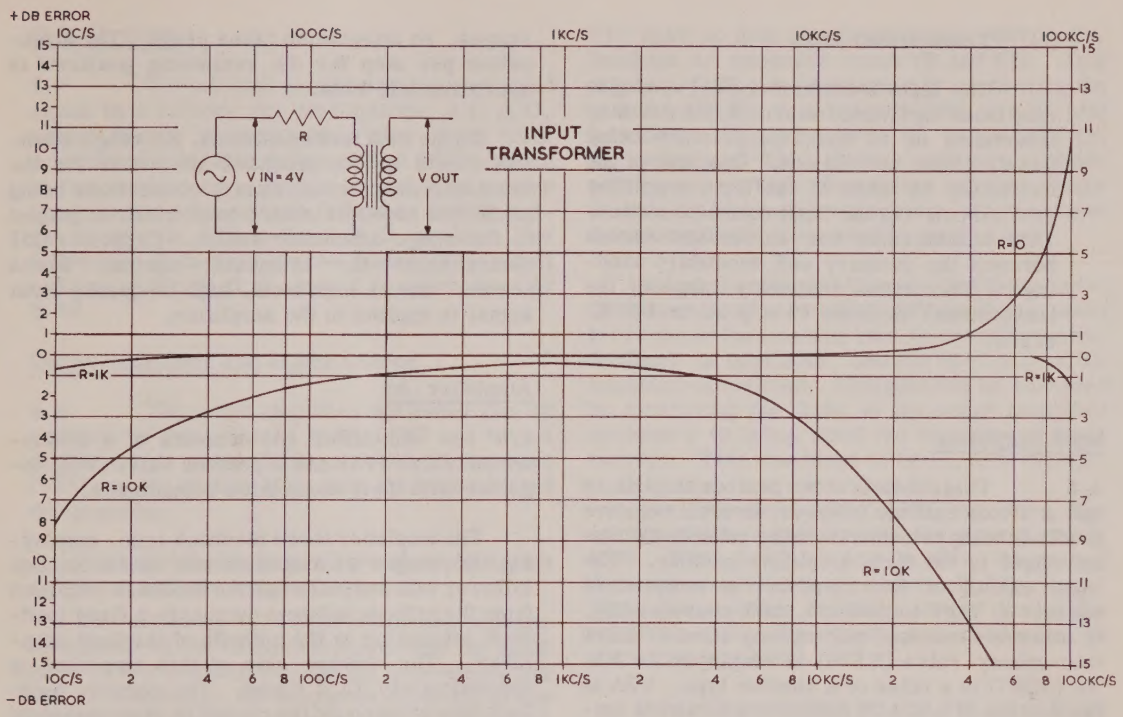


Fig. 2. Input transformer response : frequency - dB error

SECTION 4

CIRCUIT DESCRIPTION

Introduction

4.1 Basically, the A.C. Milli-voltmeter consists of four cascade connected amplifiers, incorporating negative feedback to obtain good gain stability, feeding a meter circuit. The meter circuit employs a feedback technique which, to all practical purposes, eliminates the effects of variations and non-linearities in the meter rectifying system. The sensitivity ranges of the instrument are 1.5mV, 5mV, 50mV, 150mV, 500mV, 1.5V, 5V and 15V for full-scale deflection, and the voltage across the meter circuit for full-scale deflection is the same for all ranges. The sensitivity ranges are obtained, partly by switching the negative feedback operative on the input amplifier, and partly by means of an attenuator after the input amplifier. The usefulness of the instrument is further increased by the input condition switch, by which it is possible to select an isolated input through a 1 : 1 wide band transformer or an attenuated input through a 10 : 1 attenuator. Fig. 4 illustrates in block diagram form the various component circuits which, together, constitute the A.C. Milli-voltmeter.

Input Circuit

4.2 By means of the input condition switch, the signal may be applied to the input amplifier by any one of the following circuits:-

(a) Normal Input

In this condition, the signal is fed via the input condition switch directly to the input amplifier; the input impedance is greater than 50M-ohms shunted by approximately 20pF.

(b) Attenuator Input

The input impedance of the attenuator is nominally 1M-ohm, and the attenuation ratio is 10 : 1.

The input attenuator consists of R89, R90, R91, RV1, C1, C2 and C29.

C1 is the D.C. isolating capacitor. The resistors (R89, R90, R91 and RV1) form a simple voltage divider. RV1 is a variable resistor used to pre-set the voltage division at low frequencies, and C2 and C29 are used to compensate for the effect of stray capacitance at high frequencies. C29 is a variable capacitor and is used to pre-set the attenuation at the high frequencies.

(c) Transformer Input

The input transformer (T1) is a wide band isolating transformer. It has primary inductance of 50 Hy., the primary being isolated from the chassis. One side of the secondary is taken to the input amplifier grid circuit via the input condition switch. This transformer has an earthed screen between the primary and secondary windings. The useful frequency range of the transformer is from 10 c.p.s. to 100 K. c.p.s.

Input Amplifier

4.3 This consists of two pentode amplifiers and a triode cathode follower, overall negative feedback being returned from the cathode follower output to the first amplifier cathode. The input circuit of this amplifier is required to operate at high impedance, and consequently, to minimise hum and microphony effects, a low microphony valve (EF86) is employed as V1. V2 (6BR7) is a valve of a similar type. V3A is one section of a 12AT7 double triode and is employed as a cathode follower. The input amplifier serves two functions: (1) to act as a buffer stage with a high input impedance and a low output impedance, (2) to provide the following voltage gains:-

x 10 on the 1.5mV range
x 3 on the 5mV range
x 1 on all other ranges

The input resistance on the 1.5mV range is approximately 50M-ohms, indicating a gain of 20db operative around the feedback loop. On other ranges, loop gain is correspondingly higher. To provide the gain required on each range, the range attenuator also acts as a feedback attenuator for the input amplifier. This feedback attenuator is compensated by a pre-set capacitor C30. Additional compensation is provided in the 5mV range by the capacitors C34 and C33. C4 across R3 and C25 in series with R9 between V2 anode and H.T. negative combine to prevent parasitic oscillations, by reducing the rate of phase lag with frequency.

To reduce hum and noise a resistor R98 is connected in series with V1 heater.

Range Attenuator

4.4 The range attenuator comprises R15, R16, R17, R18, R19, R20, R21, R22 and R23. It is a simple ladder attenuator and its input resistance is nominally 21,444 ohms. It has nine positions. On the first three positions, corresponding to the 1.5mV, 5mV and 15mV ranges, no attenuation takes place. The attenuation per step for the remaining positions is approximately 10db.

On the first three positions, the range attenuator acts as the feedback attenuator for the input amplifier, the necessary connections being made by a separate switch bank which is ganged to the range attenuator switch. Capacitor C31 compensates the attenuator against "break across" when a high level, high frequency input signal is applied to the amplifier.

Amplifier (A)

4.5 Amplifier (A) consists of a double-triode valve (V4) and a pentode valve (V5), together with their associated components.

The amplifier is of a feedback type, employing two stages of amplification, and a cathode follower with overall negative feedback returned from the cathode follower output via a fixed feedback attenuator to the cathode of the first amplifier. The voltage gain of this amplifier is approximately 15.5 times. The negative feedback operative round the circuit is approximately 21.5db.

Capacitor C26 in series with R93, connected from the anode of V4A to the H.T. negative rail and C28 connected across R35 in the cathode circuit of V4B, are to prevent high frequency parasitic oscillations. The capacitor C10 (coupling V5 to V4B) has a resistor (R32) connected in parallel. Its action is to reduce the overall phase advance of the circuit at low frequencies, and thus preserve good "damping".

Amplifier (B)

4.6 Amplifier (B) consists of a double triode valve (V6) and a pentode valve (V7), together with their associated components.

This amplifier is constructed along the same lines as Amplifier (A), the only difference being in the negative feedback attenuator which, in this case, contains a variable element.

In order that all sensitivity ranges of the A.C. Milli-voltmeter may be set precisely, each range has been fitted with a separate gain control potentiometer. These potentiometers are numbered RV3 to RV11 inclusive. They are connected in the negative feedback attenuator by means of a switch which is ganged to the range attenuator switch. When a range is selected, the appropriate potentiometer is connected in parallel with R76. The voltage gain of this stage is nominally 13.5 times. The negative feedback operative is approximately 22.5db.

C.R.O. Output

4.7 To facilitate monitoring the measured signal by a cathode ray oscilloscope, a C.R.O. output socket is provided. The output from Amplifier (B) is taken to the grid of V12B, which is one section of a double triode. This valve is connected as a cathode follower, and its output is fed via C15 to the C.R.O. socket. For full-scale deflection on the meter, the output voltage at this C.R.O. socket is approximately 2.5V.

Output Amplifier and Meter Circuit

4.8 The output amplifier and meter circuit consists of two pentode valves (V8 and V9), a double triode valve (V10), a double diode valve (V11) and the meter (M1), with their associated components.

This amplifier has two stages of amplification and has a cathode follower output.

The metering circuit is connected between the cathode of the cathode follower and the +50V rail. Direct coupling is used for this connection and, consequently, the quiescent potential of the cathode is arranged to be at +50V. The output from the cathode follower is fed to the double diode (V11), which is connected as a full wave rectifier for the meter (M1). When the output voltage overcomes the diode standing bias (which is approximately 2V), current flows through the diode.

The action for each half of the current is now considered. The current flows through the conducting half of the double diode and then divides through a parallel network. One branch of this network consists of the meter (M1) in series with a 1.5K-ohm resistor; the other branch of the network consists of a 1.5K-ohm resistor.

Since the resistance of the meter is negligible by comparison to 1.5K-ohms, the currents flowing through the two branches are considered equal. After passing through this parallel network, the two currents combine to flow through R53 and R54 and then to the 50V rail. The voltage produced across R54 is fed back to the cathode of V8 and provides overall negative feedback for the output amplifier and metering circuit. The voltage produced by the current through R53 and R54 is fed back to the screen grid of V8, its action being to provide decoupling for this screen grid. To maintain good damping at very low frequencies, the capacitor C17 coupling V9 and V10 has R64 connected in parallel. This resistor, in conjunction with the grid leak (R63), transfers a portion of the quiescent anode potential of V9 to the control grid of V10.

In order that the D.C. cathode potential of V10 shall be held at approximately +50V D.C., feedback is employed round V9 and V10. This negative feedback is obtained by connecting the cathode of V10 back to the grid (V9), via V9 grid leak (R68). The capacitor C16, connected from the cathode of V10, gives a measure of phase advance at very high frequencies and thus damps the amplifier at such frequencies. This reduces the susceptibility to parasitic oscillations.

Before the signal voltage applied to the meter diodes reaches the amplitude (2V peak) necessary to overcome the standing bias, no overall negative feedback is operative, and the open gain of the amplifier is realised. This gain can be assessed by measuring the input to the output amplifier necessary to bring about the inception of diode current. This was found to be 11.2mV (peak).

Now the diode bias is 2V; therefore, the open gain of the output amplifier is approximately 45db. When feedback is operative, the gain of the output amplifier is approximately 7db; therefore, the negative feedback around the output amplifier when the diodes are conducting is approximately 38db.

Due to the standing bias on V11 when there is no input to the millivoltmeter there is a very small residual indication on M1 of between $\frac{1}{2}$ and 1% of F.S.D. The effect of this error decreases with increases of meter reading.

Power Supplies

4.9 The main H.T. rail of the A.C. Millivoltmeter is supplied from a Solartron Power Supply Sub-unit 250V/50mA, AS.516. This gives an H.T. line of high stability, low output impedance, and low hum and noise level.

The stabilisation factor of the Power Supply Sub-unit AS.516 is approximately 1,000 : 1; consequently, a mains surge of 5 volts produces an H.T. surge in the order of 5mV. In view of the high sensitivity of the A.C. Milli-voltmeter, the H.T. supply to the input amplifier must be devoid of even surges as small as 1mV in amplitude. To ensure that the H.T. supply to this input amplifier meets this stringent requirement, it is fed via a surge filter circuit.

This filter circuit consists of two main parts. The first part of the surge filter is an R.C. filter comprised of R13, R14 and C7. This provides a surge-free output of approximately 180V, but at a high output impedance. To ensure good decoupling of the 180V H.T. rail supplying the input amplifier, a low source impedance is required. To obtain this, the second part of the surge filter is used. Basically, it is one section of a double triode (V3A), connected as a cathode follower, whose input is the surge-free 180V obtained as mentioned above. Therefore, the

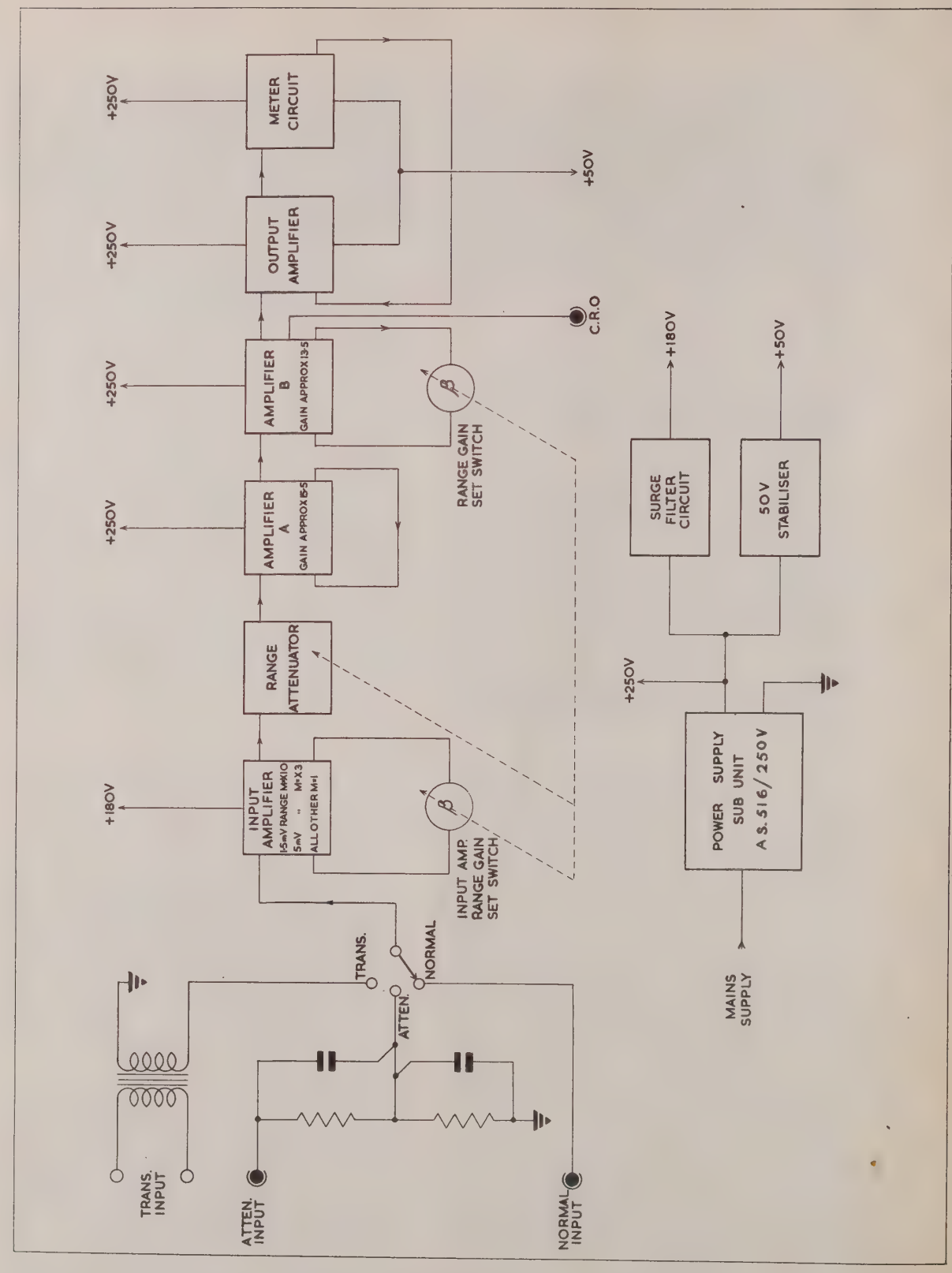


Fig. 3. The A.C. Millivoltmeter : block diagram

output from its cathode is the surge-free 180V at a low source impedance. As V3A cannot deal with the entire current required by the input amplifier, some current is fed directly from the 250V rail via R12.

The 50V rail is obtained by means of a stabiliser system, operating from the 250V rail. It comprises a double triode valve (V13) and one section of a double triode valve (V12A), together with their associated components.

The system employed is very similar to a conventional hard valve stabiliser, but it uses two stages of amplification within the control loop, in place of the usual single stage.

The 50V rail is obtained from the cathode of the series stabilising valve (V12A). The two sections of V13 form the two-stage amplifier. The overall feedback is obtained by directly coupling the cathode of the series stabilising valve (V12A) to the cathode of the first amplifier valve (V13A).

The reference voltage applied to the grid of V13A is obtained from a voltage divider network connected across the 250V rail. The variable resistor (RV12) permits precise adjustment of the rail voltage to the desired value of 50V. The source impedance of the 50V rail rises at high frequencies when the gain of the control loop falls due to its comparatively narrow bandwidth. A capacitor (C14), in series with R39, is connected from the cathode of V12A to the H. T. negative rail. The purpose of this capacitor is to produce a low source impedance at high frequencies. The resistor R39, in series with C14, prevents peaking of the source impedance at the frequency where the capacitor effectively takes over from the stabiliser circuit.

SECTION 5

SETTING UP PROCEDURE

Test Gear Required:-

Wide Range Oscillator CO546	Solartron
Calibrating Unit AT. 203	Solartron
Oscilloscope CD513	Solartron
Sub-standard A. C. Test Set	Cambridge
Avometer Model 8	

Preliminary Setting Up

5.1 Switch on all test gear and allow at least 30 minutes to warm up.

With the VF. 252 switched off, adjust the meter zero accurately. Switch on the VF. 252 and allow five minutes to warm up. Adjust RV1 on the Power Supply Sub-unit to give 250V on the H. T. rail. Adjust RV12 on the L. H. side tray to give 50V on the +50V rail. Connect a shielded 1M resistor across the normal input socket. Switch the VF. 252 input condition switch to NORMAL INPUT, and switch the attenuator switch to its most sensitive range (1. 5mV). Adjust RV2 on the L. H. side tray to give minimum reading on the meter. This should be less than one scale division on the outer scale.

Setting Up of Range Sensitivities

5.2 Set up test gear as shown below.

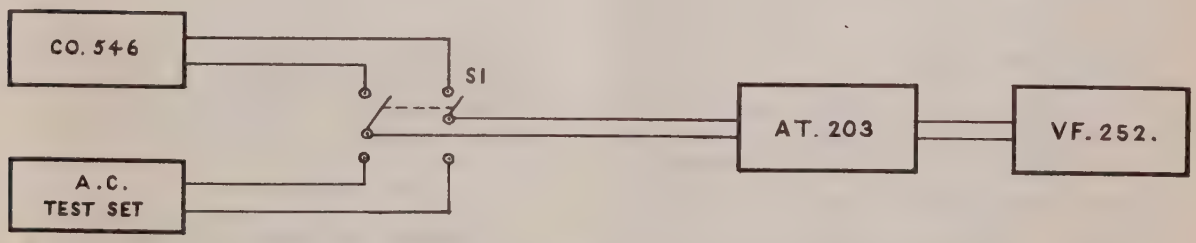


Fig. 4. Arrangement of test gear

Switch the VF. 252 to the 15V range normal input and S1 to A. C. Test Set. Switch input signal switch on AT. 203 to internal 50 c/s. Adjust coarse and fine controls so that the A. C. Test Set reads exactly 10 on the 10V range. Adjust the meter sensitivity control so that the AT. 203 meter reads exactly 10. Switch AT. 203 back to external and S1 to the CO. 546. Adjust the CO. 546 to give 10V at 1 Kc/s as shown by the AT. 203 meter.

Set up AT. 203 and VF. 252 as shown in the following table and adjust the relevant potentiometer so that the VF. 252 reads as shown.

AT. 203	VF. 252	Potentiometer	Reading
10 x 1	15V	RV11	10 inner scale
4.0 x 1	5V	RV10	4 outer scale
1.2 x 1	1.5V	RV9	4 outer scale
.4 x 1	500mV	RV8	4 outer scale
.12 x 1	150mV	RV7	4 outer scale
.4 x .1	50mV	RV6	4 outer scale
.12 x .1	15mV	RV5	4 outer scale
.4 x .01	5mV	RV4	4 outer scale
.12 x .01	1.5mV	RV3	4 outer scale

To Set Up the 10 : 1 Attenuator

5.3 Switch VF. 252 to 5V and AT. 203 to 4 x 1. Move connection from AT. 203 from normal input to attenuator 10 : 1 input and input condition switch to attenuator 10 : 1. Switch VF. 252 to 500mV range, and adjust RV1 on L. H. side tray to give a reading of 4 on the outer scale.

High Frequency Setting Up

5.4 Adjust CO. 546 to 100 Kc/s and, with other conditions as mentioned in Section 2, adjust C29 so that the meter again reads 4. Set AT. 203 to .12 x .01 and VF. 252 to 1.5mV range. Return to normal input and adjust C30 so that the meter reads 4 on the outer scale. With the AT. 203 at .4 x .01 and the VF. 252 at 5mV, adjust C33 so that the meter reads 4 on the outer scale.

External Meter Check

5.5 A telephone jack plug closed by 1K ohm should be inserted in the jack socket, when the meter deflection should change by less than 1%.

5.6 Performance Tests

5.6.1 Frequency Response

Using the input levels listed in the Setting Up Procedure, check the accuracy of the instrument at 15 c/s and 100 Kc/s on all ranges. The accuracy should be better than 1% (one half division on the outer scale).

5.6.2 Meter Scaling Error

On the 500mV range, apply a 1 Kc/s input from the AT. 203 as follows:-

.5 x 1	.2 x 1
.4 x 1	.1 x 1
.3 x 1	.05 x 1

Note that the error on the outer scale is less than one half of a scale division at all settings.

5.6.3 Mains Variation

With the VF. 252 fed at 1 Kc/s .4 x 1 from the AT. 203, swing the mains supply by means of a Variac from 255V to 205V, allowing 2 minutes at each extreme. Note that there is less than 1% variation in the meter reading.

5.6.4 C. R. O. Output

Inject a voltage into the VF. 252 at 1 Kc/s on any range, of such an amplitude as to produce F. S. D. on the meter. Observe the output at the C. R. O. socket on an oscilloscope. It should be undistorted and have an amplitude of approximately 7V peak to peak.

5.6.5 Transformer Input

With the VF. 252 on the 15V range and using transformer input, apply 10V at 1 Kc/s from CO546 through the AT. 203 and observe that the meter reads within 1%. Insert a 1K ohm resistor in series with the input signal and check that meter readings meet the following requirements:-

± 1% at 1 Kc/s
± 2% of 9.6V at 25 c/s
± 2% of 10V at 30 Kc/s

Note that as the meter in the AT. 203 is sensitive to temperature, it must be standardised against the A. C. Test Set at frequent intervals. Reading accuracy in this test must be extremely high.

5.6.6 Input Capacitance

Measure the input capacitance for normal input conditions. This should not exceed 25pF. This measurement can be made with a suitable capacitance bridge, or by connecting a capacitor of known value in series with the input socket at 100 Kc/s, and calculating the input capacitance from the change of meter reading.

SECTION 6

QUIESCENT LEVELS

General

6.1 These D.C. levels are provided for guidance only during fault finding, and should not be taken as mandatory requirements.

All measurements are made using a Model 8 Avometer and with the A.C. Milli-voltmeter in the following condition:-

(i) Input condition switch switched to normal input.

(ii) Normal input socket closed on a 1M-ohm resistor.

(iii) Range switch switched to the 15V range and the mains voltage maintained at nominal value 230V.

(iv) The main H.T. voltage set to 250V.

(v) The 50V earth set to precisely 50V.

6.2 NOTE: All readings taken with -ve lead of meter connected to frame.

Testing	+ Lead	Meter Range	Indication
V1 anode	V1/7	250V	135V
V1 screen	V1/8	250V	135V
V1 cathode	V1/3	100V	80V
V2 anode	V2/7	250V	74V
V2 screen	V2/8	250V	72V
V2 cathode	V2/3	10V	1.85V
V3a anode	V3/1	250V	181V
V3a cathode	V3/3	250V	75V
V3b anode	V3/6	250V	250V
V3b cathode	V3/8	250V	181V
V4a anode	V4/6	250V	143V *
V4a cathode	V4/8	10V	1.95V
V4b anode	V4/1	250V	250V
V4b cathode	V4/1	100V	18V
V5 anode	V5/5	250V	212V
V5 screen	V5/7	250V	60V
V5 cathode	V5/2	2.5V	.45V
V6a anode	V6/6	250V	250V
V6a cathode	V6/8	10V	2.1V
V6b anode	V6/1	250V	250V
V6b cathode	V6/3	100V	17V
V7 anode	V7/5	250V	188V
V7 screen	V7/7	250V	81V
V7 cathode	V7/2	2.5V	.77V
V8 anode	V8/5	250V	232V
V8 screen	V8/7	250V	100V
V8 cathode	V8/2	250V	50V
V9 anode	V9/5	250V	215V
V9 screen	V9/7	250V	121V
V9 cathode	V9/2	250V	50V
V10a anode	V10/6	250V	250V
V10a cathode	V10/8	100V	49V
V10b anode	V10/1	250V	250V
V10b cathode	V10/3	100V	49V
V11a anode	V11/7	100V	48.5V
V11a cathode	V11/1	100V	50.6V
V11b anode	V11/2	100V	46.8V
V11b cathode	V11/5	100V	48.7V
V12a anode	V12/1	250V	250V
V12a cathode	V12/3	100V	21V
V12b anode	V12/6	250V	250V
V12b cathode	V12/8	250V	50V
V13a anode	V13/6	250V	97V
V13a cathode	V13/8	100V	50V
V13b anode	V13/1	250V	95V
V13b cathode	V13/3	100V	47.5V

* 33K-ohms in series with Avometer to prevent parasitic oscillation.

6.3 H.T. Current: 52 M.A.
Main Consumption: 77 V.A.

FAULTS CHART VF. 252

SYMPTOM	POSSIBLE CAUSE	REMEDY
Complete failure	Fuse blown	Replace the fuse.
	Mains transformer faulty.	Check the insulation and continuity of the transformer windings.
	A. C. input wiring faulty.	Check the circuit wiring from the mains plug to the transformer primary winding.
No meter reading on all ranges.	No high-tension voltage, fault in the amplifier chain.	Check high-tension voltage. Check the amplifier by reference to the D. C. and signal voltage charts. Check valves and components in faulty section. Check the external meter socket and wiring. N. B. (when the jack is fitted to the socket, the internal meter is open circuited).
Meter reading hard over on all ranges.	Faulty high-tension supply.	Change valves in high-tension regulation circuit.
	Fault in the feedback circuits of the amplifier chain.	Check amplifier as before.
No high-tension voltage	Power supply sub-unit faulty.	Check valves and circuit components in power sub-unit.
Incorrect voltage on 50-volt line.	V12, V13 or associated circuitry.	Change V12, V13. Check circuit components. Adjust RV12 for slight errors.
Low meter reading all ranges.	Faulty amplifier.	Check the amplifier as before.
Incorrect reading on any one range.	Faulty attenuator switching. Faulty range adjustment, potentiometer.	Check the attenuator switch. Check the relevant potentiometer (RV3 to RV11).
Slight error on any one range.	Mal-adjustment.	Adjust the relevant potentiometer (RV3 to RV11).
Poor low-frequency response.	V3 faulty	Change V3.
	C6 faulty	Change C6.
Poor high-frequency response on normal input.	C30	Readjust C30 at 100 Kc/s, as in paragraph 2. 4 of the handbook.
Poor high-frequency response on attenuator input.	C29	Readjust C29 at 100 Kc/s as in paragraph 2. 4 of the handbook.
No response from the attenuator input.	C1, R89, RV1 open circuit.	Check or replace these components.
Poor response from the attenuator input.	C1, C2, R89, R90, RV1, C29.	Check or replace these components.
No response from the transformer input.	T1	Check T1.
Incorrect or no output from "C. R. O." socket.	V12 or associated circuitry.	Change V12. Check circuit components.
Continuous oscillation on meter all ranges.	Faulty N78 in power sub-unit.	Change N78.
	Wrong adjustment of mains tapping panel.	Check supply voltage and adjust mains tapping panel.

SIGNAL VOLTAGE CHECK POINTS

Inject sufficient amplitude of signal at 1 Kc/s to give full-scale deflection under normal conditions for the range selected. (Example: 15 mV on 15 mV range). Measure the voltage with a VF.252 at the following points.

TEST POINT	VOLTAGE
V3 pin 3	Input x 10 on 1.5 mV range Input x 3 on 5 mV range Input x 1 on all other ranges
V4 pin 2	12 m Volts
V6 pin 2	200 m Volts
V8 pin 1	2.85 Volts
V8 pin 5	1.1 Volts
V9 pin 5	12.5 Volts
V10 pin 8	12.5 Volts

COMPONENTS LIST

Circuit Ref.	Value Ohms	Tol. %	Rating Watts	Solartron Part No.	Manufacturer & Type	
RESISTORS						
R1	4.7M	10	1/4	226369	Erie	16 Carbon
R2	100K	2	1/4	N22269		
R3	4700	2	1/8	221141	Erie	109 H.S.
R4	2.2M	10	1/4	226365	Erie	16 Carbon
R5	39K	2	1/2	223880	S.T.C.	4304 H.S.
R6	33K	2	1/2	223878	S.T.C.	4304 H.S.
R7	47K	2	1/4	N22270		
R8	360	2	1/8	221114	Erie	109 H.S.
R9	1000	10	1/4	226325	Erie	16 Carbon
R10	22	10	1/4	226305	Erie	16 Carbon
R11	22	10	1/4	226305	Erie	16 Carbon
R12	12K	5	1	235638	Welwyn	F5 M.F.
R13	680K	1	1/2	223710	S.T.C.	4304 H.S.
R14	1.8M	1	3/4	224320	Painton	74 H.S.
R15	30K	1	1/4	N22134		
R16	30K	1	1/4	N22134		
R17	4300	1	1/8	221040	Erie	109 H.S.
R18	1500	1	1/8	221029	Erie	109 H.S.
R19	430	1	1/8	221016	Erie	109 H.S.
R20	150	1	1/8	221005	Erie	109 H.S.
R21	43	1	1/2	223609	S.T.C.	4304 H.S.
R22	43	1	1/2	223609	S.T.C.	4304 H.S.
R23	43	1	1/2	223609	S.T.C.	4304 H.S.
R24	4700	10	1/4	226333	Erie	16 Carbon
R25	1M	10	1/4	226361	Erie	16 Carbon
R26	47K	2	1/2	223882	S.T.C.	4304 H.S.
R27	1M	10	1/4	226361	Erie	16 Carbon
R28	150K	10	1/4	226351	Erie	16 Carbon
R29	56K	10	1/4	226346	Erie	16 Carbon
R30	33K	10	1/4	226343	Erie	16 Carbon
R31	330	10	1/4	226319	Erie	16 Carbon
R32	6.8M	10	1/4	226371	Erie	16 Carbon
R33	470K	10	1/4	226357	Erie	16 Carbon
R34	22	10	1/4	226305	Erie	16 Carbon
R35	5100	1	1	235166	Welwyn	Welmet M.F.
R36	360	1	1	235138	Welwyn	Welmet M.F.
R37	1M	2	1/2	223914	S.T.C.	4304 H.S.
R38	200K	2	1/8	221180	Erie	109 H.S.
R39	22	10	1/4	226305	Erie	16 Carbon
R40	470K	10	1/4	226357	Erie	16 Carbon
R41	1M	10	1/4	226361	Erie	16 Carbon
R42	1M	10	1/4	226361	Erie	16 Carbon
R43	470K	10	1/4	226357	Erie	16 Carbon
R44	56K	10	1/4	226346	Erie	16 Carbon
R45	1M	10	1/4	226361	Erie	16 Carbon
R46	1M	10	1/4	226361	Erie	16 Carbon
R47	330K	10	1/4	226355	Erie	16 Carbon
R48	22	10	1/4	226305	Erie	16 Carbon
R49	6800	10	1/4	226335	Erie	16 Carbon
R50	10	10	1/4	226301	Erie	16 Carbon

Circuit Ref.	Value Ohms	Tol. %	Rating Watts	Solartron Part No.	Manufacturer & Type	
RESISTORS (Contd.)						
R51	1500	1	1/8	221029	Erie	109 H.S.
R52	1500	1	1/8	221029	Erie	109 H.S.
R53	560	1	1/8	221019	Erie	109 H.S.
R54	1300	1	1	235152	Welwyn	Welmet M.F.
R55	27K	10	1/4	226342	Erie	16 Carbon
R56	100K	10	1/4	226349	Erie	16 Carbon
R57	1000	10	1/4	226325	Erie	16 Carbon
R58	1000	10	1/4	226325	Erie	16 Carbon
R59	24K	2	1/8	221158	Erie	109 H.S.
R60	22	10	1/4	226305	Erie	16 Carbon
R61	22	10	1/4	226305	Erie	16 Carbon
R62	4300	2	1/2	223857	S.T.C.	4304 H.S.
R63	750K	2	1/2	223911	S.T.C.	4304 H.S.
R64	2.7M	2	3/4	224524	Painton	74 H.S.
R65	33K	2	1/8	221161	Erie	109 H.S.
R66	68K	10	1/4	226347	Erie	16 Carbon
R67	100K	10	1/4	226349	Erie	16 Carbon
R68	470K	10	1/4	226357	Erie	16 Carbon
R69	22K	10	1/4	226341	Erie	16 Carbon
R70	1000	10	1/4	226325	Erie	16 Carbon
R71	180K	10	1/4	226352	Erie	16 Carbon
R72	82K	10	1/4	226348	Erie	16 Carbon
R73	1M	10	1/4	226361	Erie	16 Carbon
R74	5100	1	1	235166	Welwyn	Welmet M.F.
R75	350	1	1	235137	Welwyn	Welmet M.F.
R76	220	1	1	235133	Welwyn	Welmet M.F.
R77	22	10	1/4	226305	Erie	16 Carbon
R78	470K	10	1/4	226357	Erie	16 Carbon
R79	6.8M	10	1/4	226371	Erie	16 Carbon
R80	33K	10	1/4	226343	Erie	16 Carbon
R81	330	10	1/4	226319	Erie	16 Carbon
R82	100K	10	1/4	226349	Erie	16 Carbon
R83	56K	10	1/4	226346	Erie	16 Carbon
R84	1M	10	1/4	226361	Erie	16 Carbon
R85	47K	10	1/4	226345	Erie	16 Carbon
R86	1M	10	1/4	226361	Erie	16 Carbon
R87	10K	10	1/4	226337	Erie	16 Carbon
R88	2.2M	10	1/4	226365	Erie	16 Carbon
R89	910K	1	3/4	224313	Painton	74 H.S.
R90	100K	1	1/8	221073	Erie	109 H.S.
R91	6.8M	10	1/4	226371	Erie	16 Carbon
R92	22	10	1/4	226305	Erie	16 Carbon
R93	1000	10	1/4	226325	Erie	16 Carbon
R94	1000	10	1/4	226325	Erie	16 Carbon
R95	47	10	1/2	226509	Erie	8 Carbon
R96	3600	1	1/8	221038	Erie	109 H.S.
R97	3.9M	10	1/4	226368	Erie	16 Carbon
R98	5.6	2	1/2	N22423		

Circuit Ref.	Value Ohms	Tol. %	Rating Watts	Solartron Part No.	Manufacturer & Type
RESISTORS VARIABLE					
RV1	5000	10	½	256412	
RV2	100	10	½	256407	
RV3	250	10	½	256408	
RV4	500	10	½	256409	
RV5	250	10	½	256408	
RV6	250	10	½	256408	
RV7	250	10	½	256408	
RV8	250	10	½	256408	
RV9	250	10	½	256408	
RV10	250	10	½	256408	
RV11	250	10	½	256408	
RV12	100K	10	1	256616	

Circuit Ref.	Value µFd	Tol. %	Rating Volts	Solartron Part No.	Manufacturer & Type	
CAPACITORS						
C1	0.5	20	500	N20025	T.C.C.	CP91S
C2	4.7pF	0.25pF	500	201009	Erie	Ceramicon P100K
C3	0.02	20	500	214205	T.C.C.	CP34S (Sleeved)
C4	22pF	10	500	217609	Suflex	Polystyrene/500V
C5	33pF	10	500	217610	Suflex	Polystyrene/500V
C6	0.05	20	500	214206	T.C.C.	CP37S (Sleeved)
C7	2	25	250	206606	Hunts	W49 B510P
C8	0.25	25	250	206603	Hunts	W49 B507P
C9	0.25	25	250	206603	Hunts	W49 B507P
C10	0.05	20	350	214104	T.C.C.	CP35N (Sleeved)
C11	0.25	25	350	206704	Hunts	W49 B513
C12	0.1	20	350	214105	T.C.C.	CP37N (Sleeved)
C13	0.1	20	350	214105	T.C.C.	CP37N (Sleeved)
C14	1	25	250	206605	Hunts	W49 B509P
C15	1	25	250	206605	Hunts	W49 B509P
C16	10pF	10	500	217607	Suflex	Polystyrene/500V
C17	0.1	20	350	214105	T.C.C.	CP37N (Sleeved)
C18	0.1	20	350	214105	T.C.C.	CP37N (Sleeved)
C19	0.25	25	250	206603	Hunts	W49 B507P
C20	18pF	2	500	217416	Suflex	H.S.
C21	0.05	20	350	214104	T.C.C.	CP35N (Sleeved)
C22	0.25	25	250	206603	Hunts	W49 B507P
C23	0.25	25	250	206603	Hunts	W49 B507P
C24	1	25	250	206605	Hunts	W49 B509P
C25	47pF	10	500	217611	Suflex	Polystyrene/500V
C26	47pF	10	500	217611	Suflex	Polystyrene/500V
C27	47pF	10	500	217611	Suflex	Polystyrene/500V
C28	22pF	10	500	217609	Suflex	Polystyrene/500V
C29	3.5-30pF			N24007	T.C.C.	TCK0330
C30	3.5-30pF			N24007	T.C.C.	TCK0330
C31	0.0047	10	500	217623	Suflex	Polystyrene/500V
C32	10pF	10	500	217607	Suflex	Polystyrene/500V
C33	3.5-30pF			N24007	T.C.C.	TCK0330

Circuit Ref.	Description	Solartron Part No.	Manufacturer & Type	
VALVES				
V1			Mullard	EF86
V2			Brimar	6BR7
V3			Brimar	12AT7
V4			Brimar	12AT7
V5				CV138
V6			Brimar	12AT7
V7				CV138
V8				CV138
V9				CV138
V10			Brimar	12AT7
V11			Brimar	6AL5
V12			Brimar	12AT7
V13			Brimar	12AX7
MISCELLANEOUS				
F1	Fuse	372271		
T1	Transformer	295017	Parmeko	
M1	Meter	341011	Sangamo Weston	
SK1	Jack 800 B6 Mk. 1			
SW1	Switch Wafer	B6091		
SW2	Switch Wafer	B6092		
SW3	Switch Toggle		Painton	501085
SW4	Switch Toggle		Painton	501085

NOTE: Equivalent components by other manufacturers may be fitted in some instruments.

ABBREVIATIONS:

S. T. C.	Standard Telephones & Cables
T. C. C.	Telegraph Condenser Company
G. E. C.	General Electric Company
W. W.	Wire Wound
H. S.	High Stability
M. F.	Metal Film
Pa.	Paper
Po.	Polystyrene
M. P.	Metalised Paper
M. Pl.	Metalised Plastic
Ce.	Ceramic
El.	Electrolytic

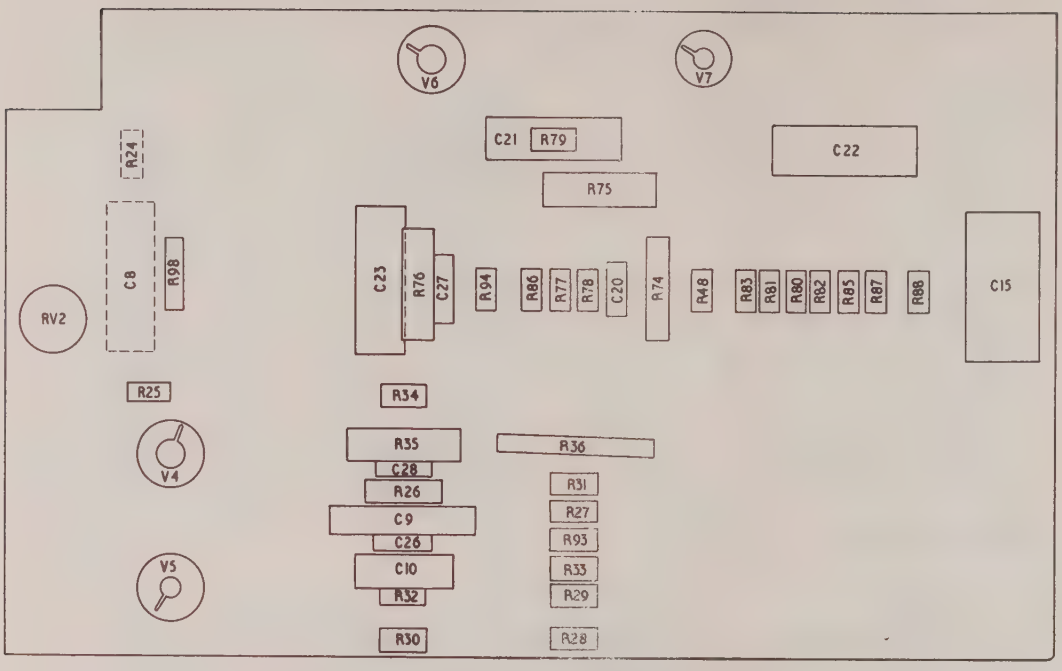


Fig. 5. Bottom chassis : Component layout

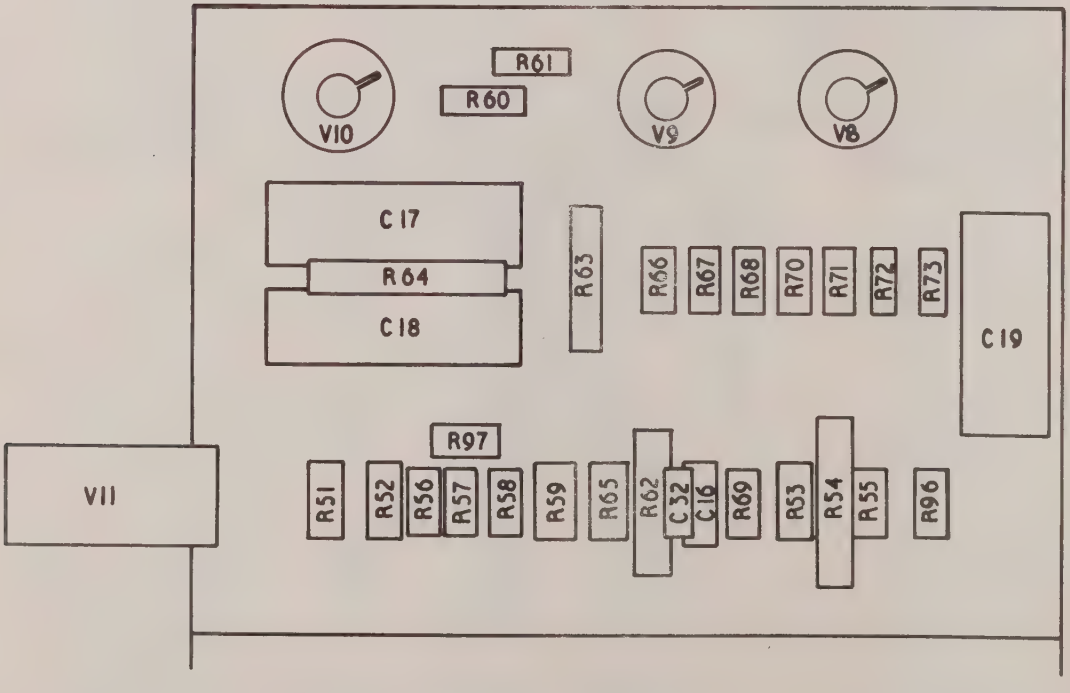


Fig. 6. Right side : Component layout

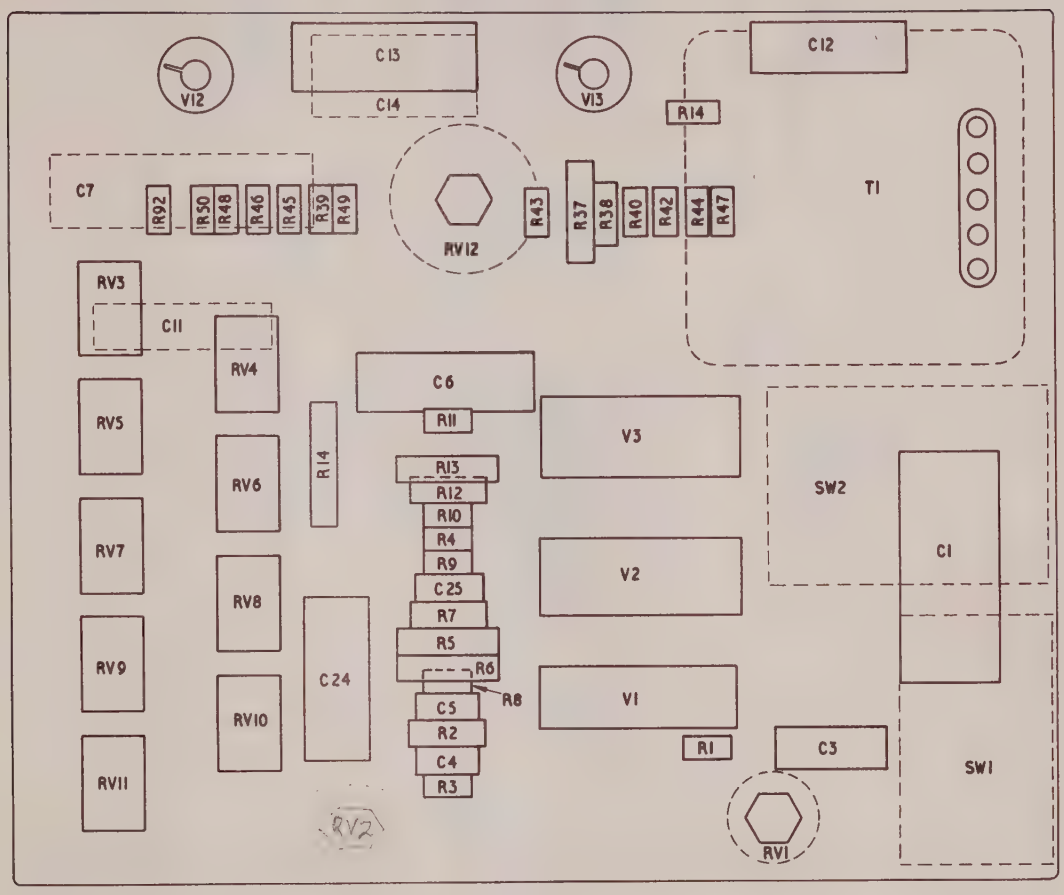


Fig. 7. Left side : Component layout

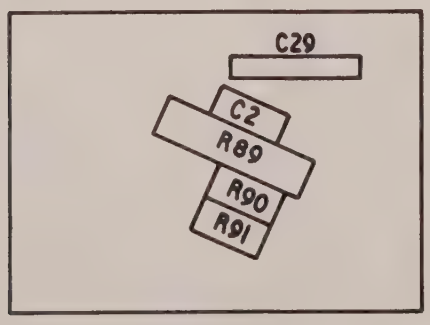


Fig. 8. Switch 1 viewed from rear : Component layout

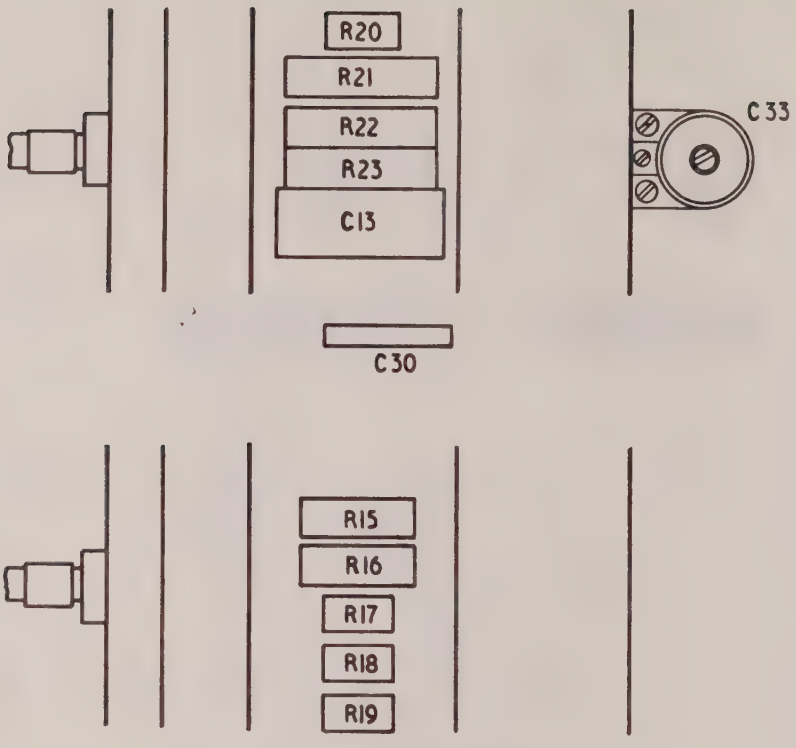


Fig. 9. Switch 2 : Component layout

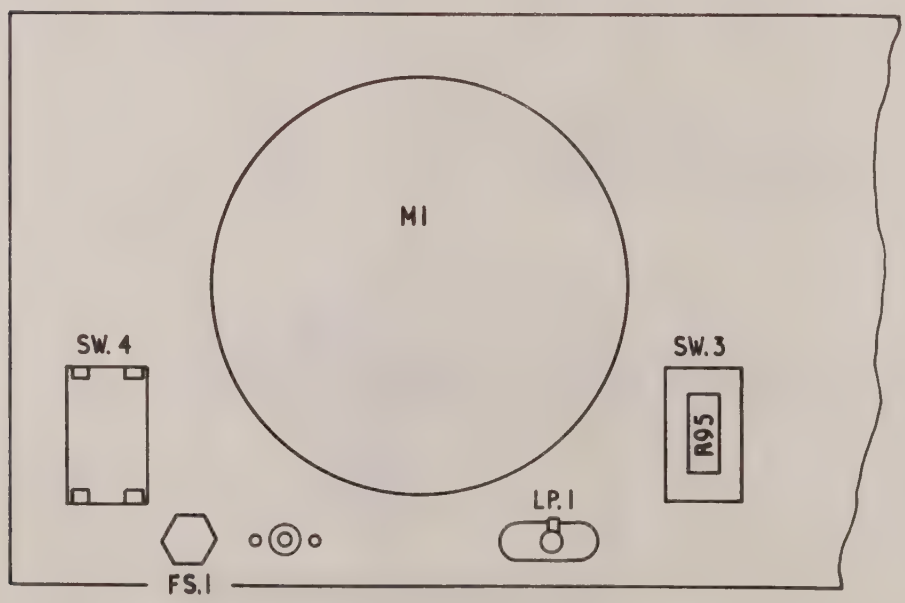
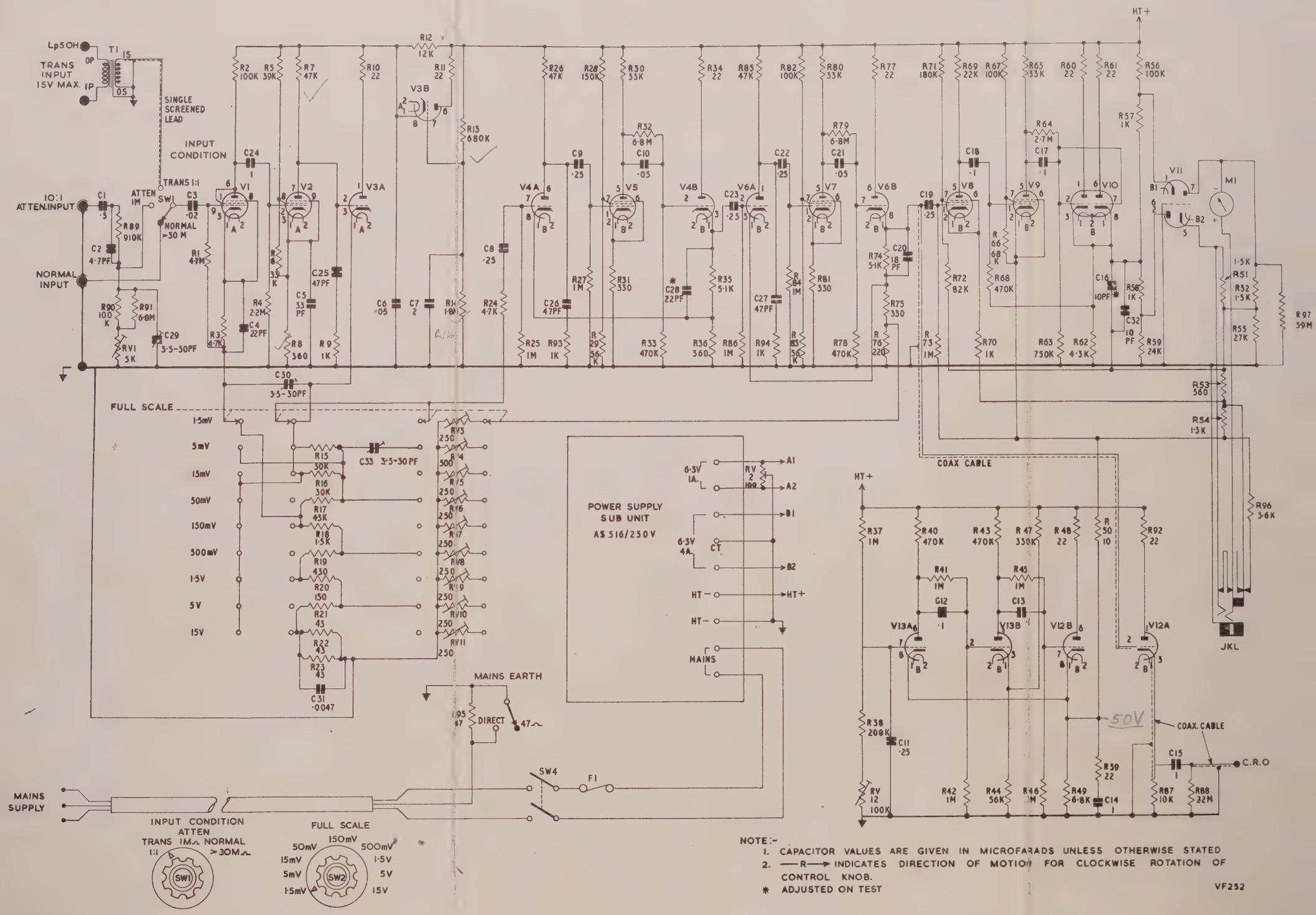


Fig. 10. Rear of front panel : Component layout



NOTE:-

1. CAPACITOR VALUES ARE GIVEN IN MICROFARADS UNLESS OTHERWISE STATED
2. ——R——→ INDICATES DIRECTION OF MOTION FOR CLOCKWISE ROTATION OF CONTROL KNOB.

* ADJUSTED ON TEST

VF252

Fig. 11. The A.C. Millivoltmeter : Circuit diagram

INSTRUCTION MANUAL
FOR
HIGH STABILITY POWER SUPPLY SUB-UNIT
AS 516

LIST OF CONTENTS

		Page
Section 1.	Introduction	2
Section 2.	Operating Instructions	2
Section 3.	Principles of Operation	2
Section 4.	Performance Specification	3
Section 5.	Circuit Description	3
Section 6.	Servicing Information	3
Section 7.	Component Lists	5

DIAGRAMS

Fig. 1:	Block Diagram	2
Fig. 2:	Component Identification	4
Fig. 3:	Circuit Diagram	6

SECTION 1

INTRODUCTION

1.1. This electronically regulated HT Power Supply Sub-Unit has been developed by the Solartron Electronic Group to provide supply units as components rather than as bench instruments. Each unit is a carefully engineered entity, ready for immediate inclusion in a research or production instrument. Many instruments from the standard Solartron Range use these units to provide highly stable HT voltages. They are also suited to the requirements of educational establishments and radio and television servicing where the small physical dimensions permit ease of use in congested work areas.

1.2. The HT lines are isolated from earth so that the units may be used go give positive or negative outputs and may be connected in series. Maximum reliability is ensured, even after long periods in store, by using only the highest quality components and no electrolytic capacitors. Each unit is mounted on a light but rigid sub-assembly frame provided with fixing points and angle brackets to permit fixing in any plane.

SECTION 2

OPERATING INSTRUCTIONS

2.1. Check that the mains tapping panel is correctly set.
2.2. Connect the power unit as required, making sure that the chassis is suitably earthed.
2.3. Switch on, and check that the output voltage is correct. This voltage may be adjusted $\pm 5\%$ approximately by means of the preset potentiometer RV1.
2.4. To change from 250V output to 300V output. Remove the connections from pin 10 and pin 12 on T1 and replace them on pin 9 and pin 13. Adjust the linking on the S.R.B.P. panel, which is situated under the chassis to 300V. To change from 300V output to 250V output reverse this procedure.

SECTION 3

PRINCIPLES OF OPERATION

3.1. The circuit used in each of these power units is composed of:—

1. A Stable Voltage Reference.
2. A Sampling Chain.
3. A Wide-band DC Amplifier.
4. A Series Control Valve.
5. An Unstabilised Power Supply.

These are connected together as shown in the accompanying block diagram (Fig. 1).
3.2. A proportion of any change which appears on the stabilised output is fed through the sampling chain into the wide-band DC amplifier. It is then amplified and fed to the grid of the series control valve. This alters the volt drop across the series valve in such a sense as to oppose the initial change. The final magnitude of the change is a function of the gain of the wide-band DC amplifier.

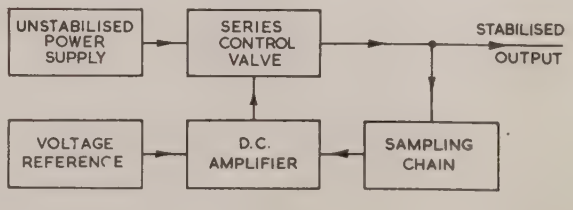


Fig 1.

SECTION 4

PERFORMANCE SPECIFICATION

D.C. OUTPUT VOLTAGE	D.C. OUTPUT CURRENT	A.C. OUTPUTS	D.C. SOURCE IMPEDANCE	STABILITY FACTOR	A.C. SOURCE IMPEDANCE (40 c/s-100 Kc/s)
±250 V ±300 V	0–50 mA	6·3 V 4 A C.T. 6·3 V 1 A	<1 Ω	>400 : 1	<0·25 Ω

RIPPLE AND NOISE CONTENT	PERMISSIBLE SUPPLY DEVIATION	POWER INPUT	OVERALL DIMENSIONS	WEIGHT
<250 μV	±7%	110 V or 220 V ±20V 40 c/s–60 c/s	9⅛" × 6⅛" × 6¼" high (23 cms × 15 cms × 16 cms)	14½ lbs. (7 Kgs.)

SECTION 5

CIRCUIT DESCRIPTION

The circuit is described in the five sections mentioned in the principles of operation.

5.1. The voltage reference is a Mullard 85A2 operating at a current between 4 and 6 mA according to the output voltage setting. This valve has a burning voltage of 85 V.

5.2. The sampling chain is a series of high-stability carbon resistors connected between the stabilised HT + and HT −. It acts as a potential divider supplying various points in the wide-band DC amplifier at appropriate potentials.

5.3. The wide-band DC amplifier consists of a Z77 pentode for the first amplifier, followed by a double-triode connected as a cathode-coupled stage. The cathode of the Z77 is connected through a 100Ω stopper resistance to the 85A2 so that it is held at a constant potential of approximately 85 V. The screen of the Z77 is fed from a potential divider, and the grid is connected to the sampling chain through the diode V6. The purpose of the diode is to give first order compensation to the DC drift introduced by heater-voltage changes. The output of the pentode is applied to a double triode which is connected as a cathode-coupled differential amplifier receiving its other input signal from the sampling chain. The output of the cathode-coupled amplifier is directly coupled to the control grid of the series control valve.

5.4. The series control valve carries most of the current drawn from the stablised rail, but some current is allowed to by-pass the valve through a resistance.

5.5. The unstabilised power supply is of conventional form, consisting of a transformer feeding a full-wave rectifier and a capacitor input filter.

SECTION 6

SERVICING INFORMATION

6.1. Performance Tests

6.1.1. Supply the unit with nominal mains, and correctly load all the AC and DC ouputs. The voltage at the AC outlets should be ± 3% of nominal. The DC potential can be accurately set by adjusting RV1.

6.1.2. Monitor the DC stabilised line with a C.R.O. to ensure the absence of parasitic oscillations. Using an AC millivoltmeter check that the hum and noise present on the DC output is less than that specified. The chassis should be earthed for this test.

6.1.3. Check that the changes of DC output are not measurable when the HT current is changed from full load to the permissible minimum, and when the mains input is varied ± 7% about normal.

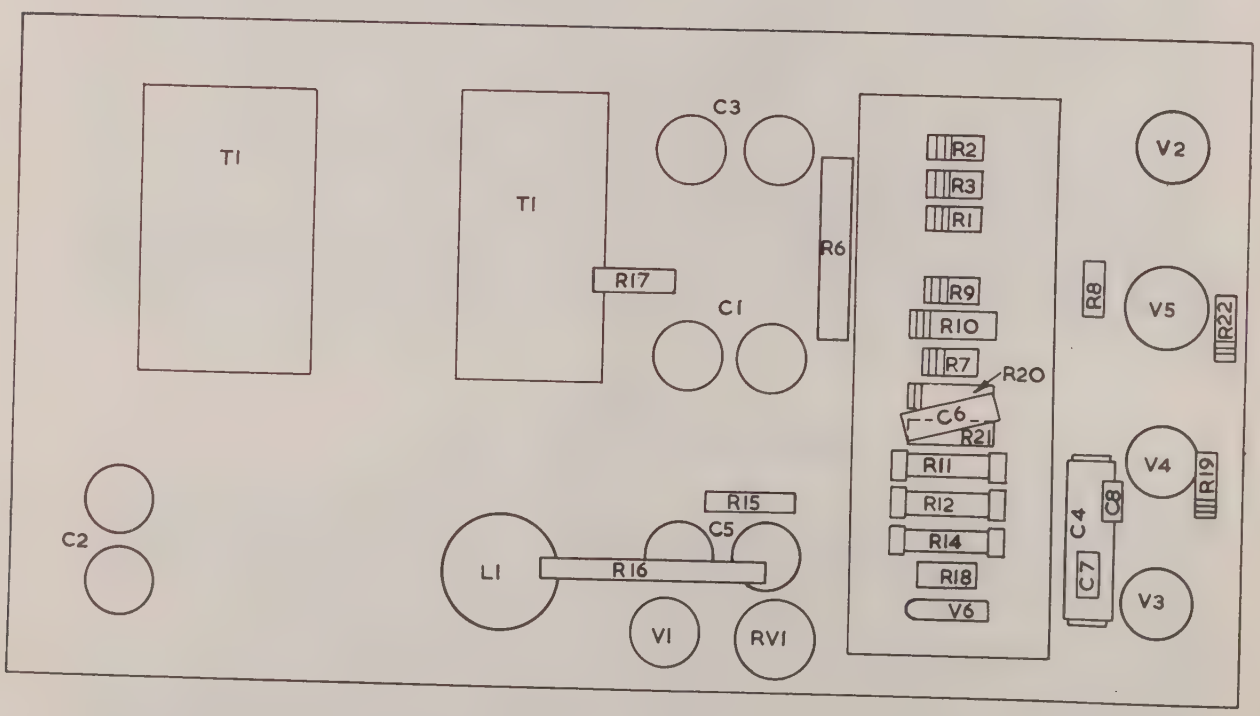
6.1.4. The AC source impedance is measured by driving 5 mA AC into the stabilised output through a suitable capacitor, and measuring the AC potential across the output.

6.2. Quiescent Potentials

6.2.1. These potentials are supplied for information only and are not mandatory requirements. They were measured using an Avo Model 8 with its negative terminal attached to HT negative. The power-supply sub-unit was operating at full load and supplied at nominal mains potential.

AS 516

	250 V 50 mA		300 V 50 mA	
V1 Pin 3	460	1000	460	1000
V2 ,, 5	450	1000	458	1000
,, 7	448	1000	456	1000
,, 2	250	1000	300	1000
,, 1	238	250	262	1000
V3 ,, 5	82	250	82	250
V4 ,, 5	155	250	178	250
,, 6 & 2	82	250	82	250
,, 7	150	250	120	250
,, 1	82	250	82	250
V5 ,, 1	250	250	300	1000
,, 2	155	250	178	250
,, 3 & 8	160	250	191	250
,, 7	154	250	177	250
,, 6	238	250	258	1000
V6 Anode	82	250	82	250



COMPONENT LOCATION

COMPONENT LISTS

NOTES: 1. Blank space indicates no change from the line above.
2. In some instruments direct equivalents from other manufacturers have been used.
3. Abbreviations:

H.S.	High Stability
W.W.	Wire Wound
Po	Polystyrene
T.C.C.	Telegraph Condenser Company
S.T.C.	Standard Telephones & Cables
G.E.C.	General Electric Company
	Sleeved

Resistors

CCT. REF.	VALUE OHMS	TOL. %	MANUFACTURER	TYPE	RATING WATTS
R1	220	10	Erie	9 Carbon	$\frac{1}{4}$
R2	22	10			$\frac{1}{4}$
R3	220k	10			$\frac{1}{4}$
R4	Not fitted				
R5					
R6	39k	5	Painton	P305 W.W.	6
R7	100	10	Erie	9 Carbon	$\frac{1}{4}$
R8	470k	10			$\frac{1}{4}$
R9	22	10			$\frac{1}{4}$
R10	47k	5	Morgan	R Carbon	1
R11	39k	1	Painton	74 H.S.	$\frac{3}{4}$
R12	30k	1	Erie	108	$\frac{1}{4}$
R13	Not fitted				
R14	30k	1	Painton	74 H.S.	$\frac{3}{4}$
R15	1M	5	Erie	108	$\frac{1}{4}$
R16	47k	5	Painton	P302 W.W.	6
R17	68	5	Morgan	R Carbon	1
R19	82k	1	Erie	109 H.S.	$\frac{1}{8}$
R19	150k	10		9 Carbon	$\frac{1}{4}$
R20	68k	10		8	$\frac{1}{2}$
R21	47k	10			$\frac{1}{2}$
R22	47k	10		9	$\frac{1}{4}$
RV1	5k	10	Colvern	CLR 1206/9S	$\frac{1}{2}$

Capacitors

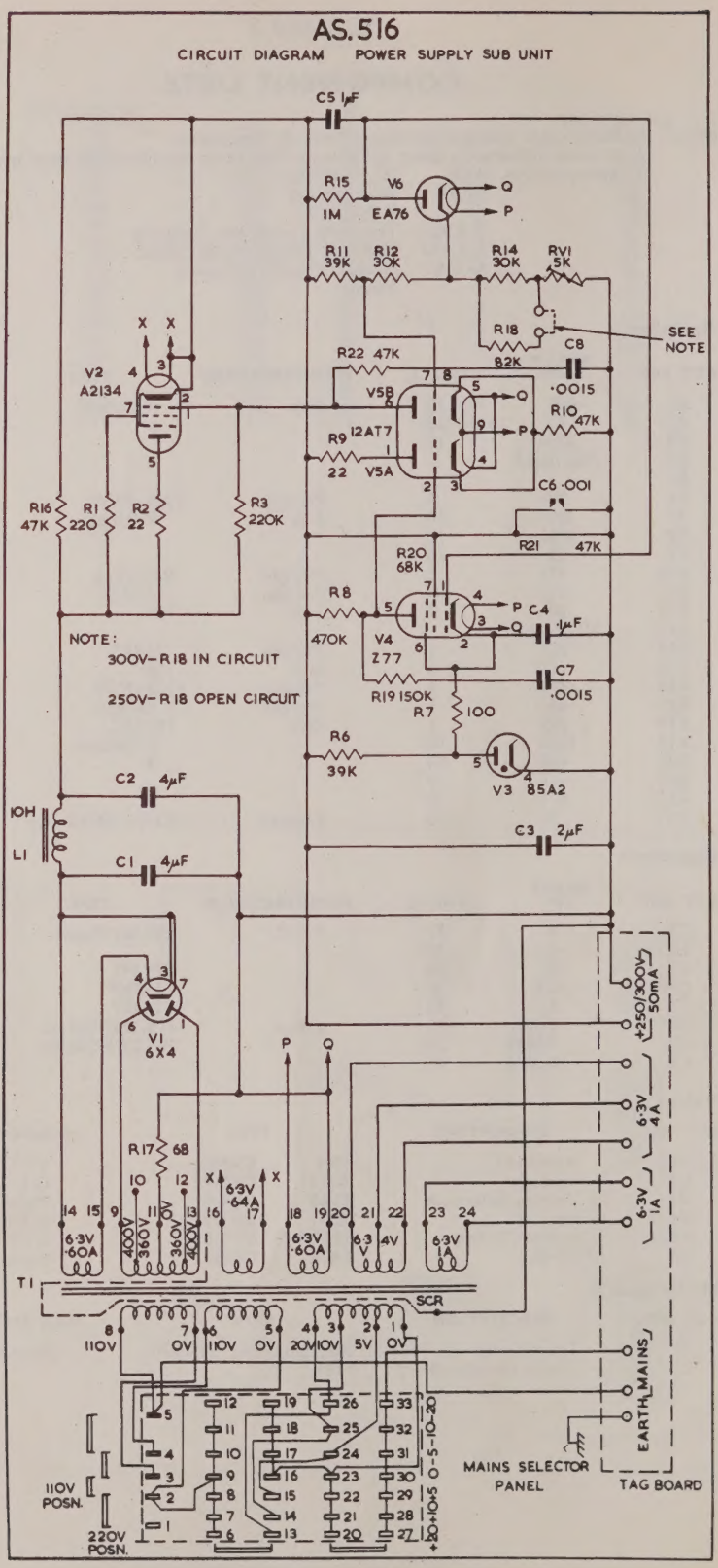
CCT. REF.	VALUE µF	TOL. %	MANUFACTURER	TYPE	RATING VOLTS
C1	4	20	T.C.C.	CP149V Paper	800
C2	4	20			800
C3	2	20		CP144T	600
C4	0·1	20		CP37N*	350
C5	1	20		CP142T	600
C6	0·001	10	Suflex	H.S.2307/500 Po	500
C7	0·0015	10		H.S.2310/500 Po	500
C8	0·0015	10			500

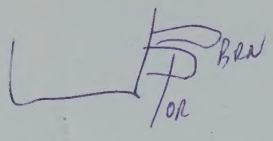
Valves

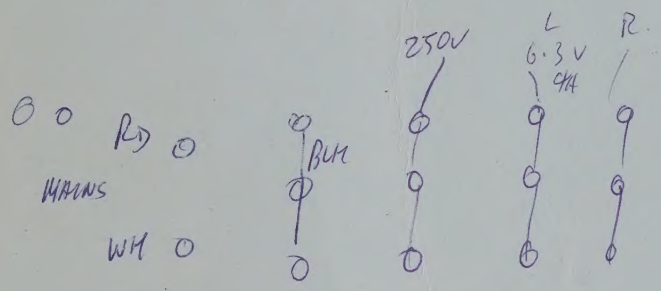
CCT. REF.	DESCRIPTION	TYPE		MANUFACTURER
V1	Rectifier	6X4	CV493	S.T.C
V2	Pentode	A2134	CV2179	G.E.C.
V3	Voltage Reference	85A2	CV449	Mullard
V4	Pentode	Z77	CV138	G.E.C
V5	Double Triode	12AT7	CV455	S.T.C
V6	Diode	EA76	CV469	Mullard

Miscellaneous

CCT. REF.	DESCRIPTION	TYPE	MANUFACTURER
T1	Transformer	Solartron Spec. 295067	Parmeko
L1	Choke 10Hy75mA	P169	


AS.516
CIRCUIT DIAGRAM POWER SUPPLY SUB UNIT
C5 1μF
R15 1M
V6 EA76
Q
P
R11 39K
R12 30K
R14 30K
RV1 5K
R18 82K
SEE NOTE
C8 ·0015
R22 47K
V2 A2134
V5B
V5A
12AT7
R10 47K
R9 22
C6 ·001
R16 47K
R1 220
R2 22
R3 220K
R21 47K
R20 68K
R8 470K
V4 Z77
C4 ·1μF
C7 ·0015
R19 150K
R7 100
R6 39K
V3 85A2
NOTE:
300V-R18 IN CIRCUIT
250V-R18 OPEN CIRCUIT
C2 4μF
C1 4μF
C3 2μF
10H
L1
V1 6X4
R17 68
6·3V ·64A
6·3V ·60A
400V
360V
400V
6·3V ·60A
6·3 V
4V
6·3V 1A
T1
SCR
110V
0V
110V
0V
20V
10V
5V
0V
+250/300V 50mA
6·3V 4A
6·3V 1A
EARTH
MAINS
110V POSN.
220V POSN.
0-5-10-20
+10+5
MAINS SELECTOR PANEL
TAG BOARD


BRN
OR


250V
L
6.3V
CT
R
RD
MAINS
WH
BLK